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Light Power Control for a Greenhouse

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ABSTRACT: Since ancient times, agriculture has been affected by external factors provided by the environment, such as rain, cold, wind, etc. That is why, over time, solutions have been seen so that these factors do not alter the final harvest. One of these alternatives to conventional agriculture is the implementation of a greenhouse, however, it is always necessary to have control of climatic conditions within it that allow improving the quality of the crops. It may be thought that said condition control can only be applicable for mass production, however, it is also sought to control the temperature for small spaces through the implementation of an integral proportional controller that manages to keep the temperature stable, modifiable and that reacts to disturbances over time.

KEYWORDS: PI controller, Transfer function, Step response, Arduino.

I. INTRODUCTION

Greenhouse plant production technology has reached heights unthinkable just 30 years ago. Both the materials and the techniques and procedures have advanced so considerably that the increase in production and quality makes possible the profitable use of high-quality materials, skilled and specialized labor. Its use, which was initially conceived for the production of ornamental herbaceous and woody plants such as roses, has been extended to the production of fruit and citrus nurseries and, currently, the cultivation of woody fruit trees in greenhouses, for fruit production. , constitutes a new concept of fruit growing that will undoubtedly change the mentality about the current fruit crop, resembling its use, more and more, to the cultivation and production of herbaceous plants.

Production inputs include some factors traditionally used such as water, fertilizers and labor. However, advances in knowledge of production techniques and plant physiology have allowed the use of new factors that increase quality, production and also allow not only reaching the initial objective of the greenhouse, which was basically production out of season, but it goes far beyond it by considerably increasing quality and production, by being able to schedule the production of a product for a specific day, etc., and all of this including new production factors such as: irrigation with water control pH and conductivity of the nutrient solution (which combines two traditional factors, improving its efficiency), hydroponics and soilless cultivation techniques, lighting control adapting it to the needs of the crop at all times, carbonic fertilization, the use of products phytosanitary through the same irrigation network, the use of systems that allow adapting the ambient humidity to the needs of the crop, air and soil heating systems, etc., and also all this with the highest level of regulation, according to the needs of the crop, in a simple way and with the minimum cost, thanks to the computer revolution of the latest 20 years, which not only allows the processes to be automated, but also allows them to be varied automatically and intelligently, depending on the climatic factors, which in turn are collected by an automatic weather station, located in the same place as the greenhouse, and finally the process can be controlled, modified, or even repaired remotely, without the need to visit the greenhouse, thanks to the integrated use of programmable controllers. All this makes possible a great efficiency of the set of resources used at the minimum cost, so that greenhouse production technology is increasingly important and profitable compared to other production systems.

Paper is organized as follows. Section II describes works related to the design of controllers for greenhouses. The process of designing and obtaining parameters of the controller is given in Section III. Section IV presents experimental results showing results of controller behavior. Finally, Section V presents conclusion.

II. RELATED WORK

The objective of greenhouse climate control is to improve the culture development and to minimize the production costs. In [1], the authors propose a comparison between two approaches to modelling and control greenhouse's inside climate. This one is defined by internal temperature and hygrometry. The classical approach is based on a single linear model to describe the dynamic of greenhouse internal climate and using a strategy control to regulate



the microclimate inside the greenhouse. The multi-modelling approach aims to reduce the complexity of the system in terms of variables to take into account in modelling and controllers design.

In [6] reveals an idea of environmental monitoring and greenhouse control using a sensor network. The hardware implementation shows periodic monitoring and control of greenhouse gases in an enhanced manner. Future work is concentrated in application of the same mechanism using wireless sensor network.

In [2] examines new ways to control internal greenhouse temperature using two types of controllers: PID and PI-intelligent. The two controllers give good results, except that the PID requires a method of parameters identification, which should be valid for a large time as possible. It is therefore necessary to repeat the chosen identification technique face to change unexpected of external parameters. However, the PI-intelligent controller permits to keep the adjusted gain for a long time thanks to actualised identification and resulted by algebraic method. In order to visualize the evolution of climatic parameters in real time, a graphic interface has been developed.

In [3] it is shown that the “intelligent” controllers which are associated to the recently introduced model-free control synthesis may be easily implemented on cheap and small programmable devices.

III. METHODOLOGY

The transfer function of the system was obtained from the experimental data obtained, this was achieved by applying a step input directly to the plant and based on this, the values obtained at the output were recorded, based on this, it can be determined what kind of system it is. It was established that the system is first order and would be as follows:

$$G(s) = \frac{k}{\tau s} + 1$$

The transfer function was performed by collecting data reflected by the MF52-103 thermistor. To obtain these values, the thermistor was placed in the object to be measured for temperature (incandescent bulb), which was connected to a dimmer to regulate the power (intensity) of the bulb, in this the input step of 100 power was imposed to observe the rate of change of the temperature measured by the thermistor. The data was observed until a stable temperature was obtained and from there the data began to be collected in the Arduino and there was a total of 247 rows of data, in the case of the temperature it was divided into 2 columns, one was the temperature captured by the Arduino and the other was the reason for the temperature change until it stabilized.

For the calculation of k (gain) the last data of the rate of temperature change was taken and divided by the input step of 100 power, resulting in the following:

$$k = \frac{59.5}{100} = 0.595$$

For the calculation of τ (time constant) the following procedure was carried out:

$$(0.623)(59.5) = 37.06$$

The value obtained refers to the rate of change in temperature, therefore, the time τ in which said data was obtained was sought, which was $\tau = 51$. After obtaining the sought τ , a new column was generated in the table using the following formula:

$$(k)(100)(1 - e^{-\frac{t}{\tau}})$$

Once the column was generated, the square of the difference of the theoretical data and the experimental data was obtained in order to extract the error, and through the spreadsheet data tab the solve option was used, configuring to obtain the minimum error modifying τ and thus obtaining the most exact value of it, resulting in the following:

k	0.595
tau	51.5167571

Finally, the data obtained in the transfer function of a first-order system were substituted, remaining as follows:



$$G_p(s) = \frac{0.01155}{s + 0.0194}$$

To find the error in a stable state, the system input type was first established, in this case it is of the step type. The system is of type 0, so the error in steady state is constant:

$$ess = \frac{R}{1 + K_p}$$

$$K_p = \lim_{s \rightarrow 0} G(s)$$

Evaluating the limit to get the constant and substituting into the equation, the error in steady state is as follows:

$$K_p = \lim_{s \rightarrow 0} G(s) = \frac{0.595}{1} = 0.595$$

$$ess = \frac{1}{1.595} = 0.627 = 62.7\%$$

The controller that was used was of the PI type since the transfer function does not have any pole at the origin; In the same way, as previously mentioned, the system is of type 0, so it was sought to convert the system to type 1, in order to achieve that the error in stable state is zero. The transfer function of the PI controller is as follows:

$$G_{c(s)} = K_p + \frac{K_i}{s} = \frac{K_p + K_i}{s} = \frac{K_p(s + K_i/K_p)}{s}$$

where

K_p = Constant of proportionality

K_i = Constant of the integral part

The transfer function is defined as:

$$KG_p(s)H(s) = \frac{0.595K}{51.52s + 1}$$

For the controller design, three settling times of the system were tested: $T_{s1} = 50$ sec., $T_{s2} = 100$ sec. and $T_{s3} = 200$ sec. These times were taken to avoid sudden changes in the system (damage to the focus), as well as not to affect the plants due to sudden increases in temperature.

For $T_{s1} = 50$ sec, it is known that the closed-loop time constant is $\tau = T_{s1}/4 = 12.5$ sec., therefore, the following relationship can be reached:

$$\tau_1 = 12.5 = \frac{1}{a} \rightarrow \alpha = 0.08$$

Based on this, the transfer function of the controller is as follows:

$$G_c(s) = \frac{K_p(s + 0.01)}{s}$$

Zero was assigned in this way because it is sought to be the closest to the origin without being completely zero. Once the transfer function of the system and the controller were obtained, the magnitude criterion was applied to obtain K_p :

$$|K_p| = \left| 1 + \frac{s(51.52s + 1)}{0.595(s + 0.01)} \right|_{s=-0.08} = 5.995$$

Therefore, the transfer function of the PI controller would be as follows:



$$G_c(s) = \frac{5.995(s + 0.01)}{s}$$

The following response was obtained in Matlab for a step input of 20:

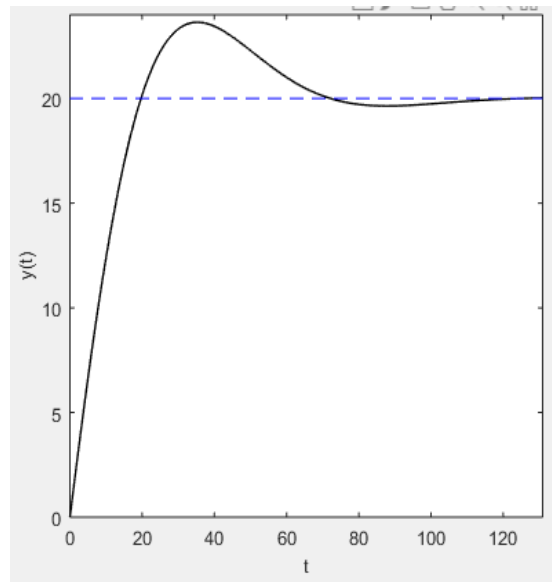


Fig. 1. Step response for a $T_{s1} = 50$ sec.

For $T_{s2} = 100$ sec., it is known that the closed-loop time constant is $\tau = T_{s2}/4 = 25$ sec., therefore, the following relationship can be reached:

$$\tau_2 = 25 = \frac{1}{\alpha} \rightarrow \alpha = 0.04$$

Zero was assigned in this way because it is sought to be the closest to the origin without being completely zero. Once the transfer function of the system and the controller were obtained, the magnitude criterion was applied to obtain K_p :

$$|K_p| = \left| 1 + \frac{s(51.52s + 1)}{0.595(s + 0.01)} \right|_{s=-0.04} = 2.377$$

Therefore, the transfer function of the PI controller would be as follows:

$$G_c(s) = \frac{2.377(s + 0.01)}{s}$$

The following response was obtained in Matlab for a step input of 20:

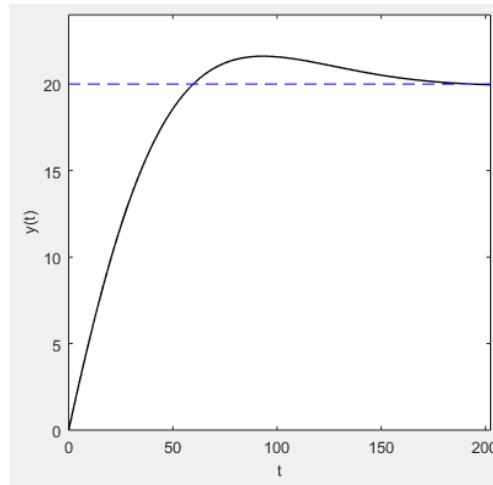


Fig. 2. Step response for a $T_{s2} = 100$ sec.

For $T_{s3} = 200$ sec., it is known that the closed-loop time constant is $\tau = T_{s3}/4 = 50$ sec., therefore, the following relationship can be reached:

$$\tau_2 = 50 = \frac{1}{\alpha} \rightarrow \alpha = 0.02$$

Zero was assigned in this way because it is sought to be the closest to the origin without being completely zero. Once the transfer function of the system and the controller were obtained, the magnitude criterion was applied to obtain K_p :

$$|K_p| = \left| 1 + \frac{s(51.52s + 1)}{0.595(s + 0.01)} \right|_{s=-0.02} = 0.1022$$

Therefore, the transfer function of the PI controller would be as follows:

$$G_c(s) = \frac{0.1022(s + 0.01)}{s}$$

The following response was obtained in Matlab for a step input of 20:

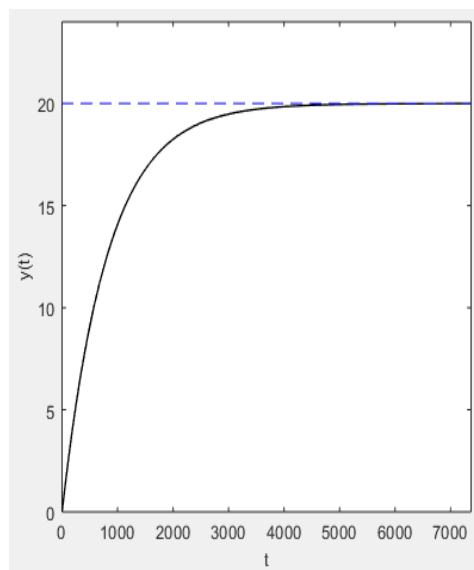


Fig. 3. Step response for a $T_{s3} = 200$ sec.

It was observed that, for greater practicality for the operation of the controller in the Arduino program, $K_p=5$ and zero(z) were taken as $z=1/51.52$, since with this the transient part of the system would be modified. The following graph was obtained in Matlab for a step input of 20.

We proceeded to put a step input of 20 in the Arduino program, which was taken as one of 50 due to having an initial temperature of 30 degrees. That is, it was sought that the system had a temperature of 50 degrees.

IV. EXPERIMENTAL RESULTS

In Fig. 4 the implemented control system is shown, where there is an Arduino microcontroller as a PI controller, an arrangement of lights that provide the desired temperature and the reference to establish the appropriate temperature value.

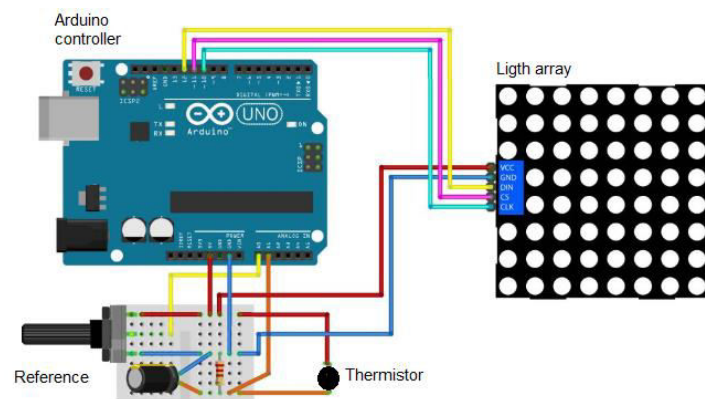


Fig. 4. Control system for the greenhouse.

The PI parameter was plugged into the experimental controller as depicted in Fig 5. Some fluctuations existed in the theoretical curve at the intersection with the set-point. However, a good tracking of the setpoint is demonstrated with a maximal error of 0.3 °C. This controller was easy to implement and was very effective in tracking the set-point.

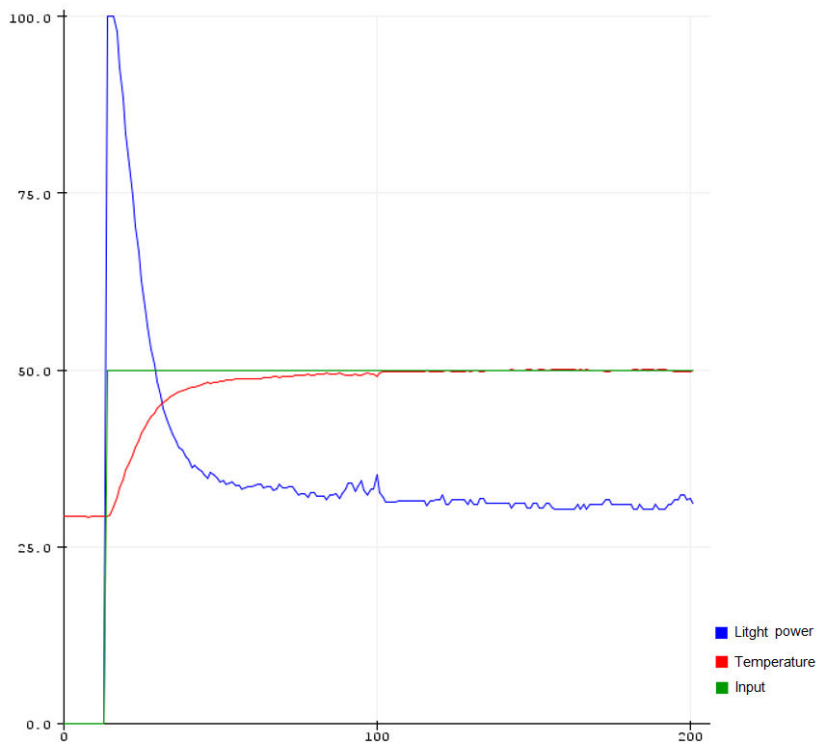


Fig. 5. Temperature under greenhouse by PI.

Subsequently, in order to check the behaviour of the controller when a disturbance occurs in the system, the following results were obtained as shown in Fig. 6. As can be seen, despite the disturbances presented in the system, it manages to return to the desired temperature without any problem. Likewise, if there are disturbances or interruptions to the system, it regulates itself again and maintains its stability.

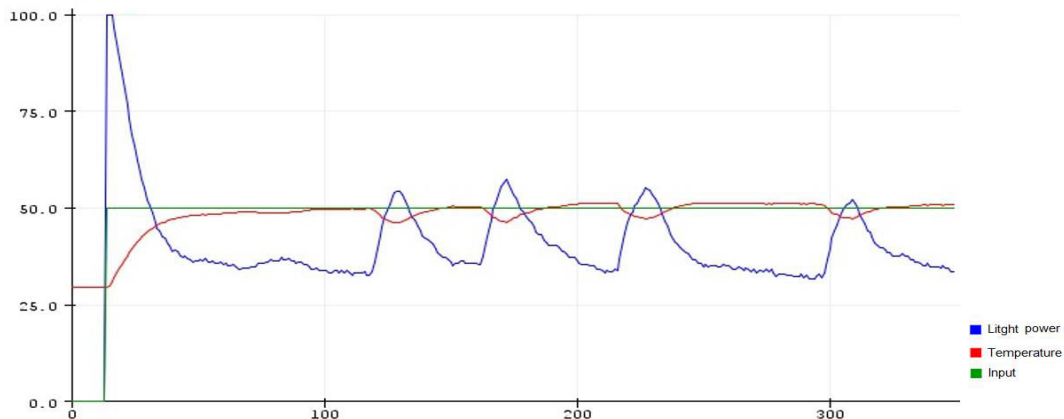


Fig. 6. Controller behaviour in the event of disturbances.

V. CONCLUSION

This paper presents the implementation of a PI which was been implemented in order to control the temperature of a greenhouse. The fundamental difficulty with the PI controller is a feedback system with constant parameters and no direct knowledge of the process, so the overall performance must best match the actual operating conditions of the process. However, the tuning of several controllers in the complex greenhouse environment is a challenge to process. PI controllers, when used alone, can give poor performance when the PI loop gain must be reduced so that the output trajectory oscillates around the set-point value with no overshoot. They also have difficulties in the presence of non-linearities, sometimes do not react to changing behavior of the process and are slow to respond to large disturbances.

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